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Conditioned Export-Led Growth Hypothesis:
A Panel Threshold Regressions Approach

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Abstract

This paper proposes a reassessment of the export-led growth hypothesis focusing on conditioning effects from countries initial level of GDP per worker, human capital stock, and exports share in GDP. For this purpose a panel threshold regression technique was applied over selected cross-country panel data, covering a broad sample of 72 countries and two sub-samples over the period from 1974 to 2003. Special attention was given to the 5-years data averaging procedure, using panel unit root tests, and to the variables measures choice, where a sensitivity analysis is proposed. Overall, the evidence reported favors the export-led growth hypothesis, where the relationship between exports and growth was showed to be not as trivial as linear specifications would indicate.

Keywords: export-led growth, panel threshold regressions, trade and growth.

JEL Classification: F43, O11, O40, O50.

1. Introduction

The relationship between exports and economic growth is one of the most extensively researched issues on the empirical literature of growth and development. The debate on whether countries should promote the export sector to obtain economic growth culminated into what is known as the export-led growth (ELG) hypothesis. According to this hypothesis, countries which adopt an outward orientation tend to obtain better economic performances.

According to Edwards (1991, p. 5) models incorporating positive effects from trade to growth are related to an important insight developed by W. Arthur Lewis (1955) which argued that those developing countries that are more integrated to the rest of the world will have an advantage in absorbing technological innovations generated in the advanced nations. This insight can be formalized as a “learning-by-looking” type of process where the mere contact with newer commodities and technologies increases the innovations absorption efficiency, which is the general idea behind the models of Edwards (1989), and, Grossman and Helpman (1991a). Another common way of modeling Lewis insight is provided by Feder (1983) who

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considers the possibility of externality effects from the outward-oriented production, which is exports, to the overall economy.

Still on the theoretical grounds, Thirlwall (2000, p. 6) says that economic theories that point out to the existence of advantages from trade liberalization identify two types of gains: static gains, and dynamic gains. While the static gains are obtained by resources reallocation from a less productive sector to a higher one, leading to specialization[2], the dynamic gains associate international trade with the increase of investments and faster productivity growth based on scale economies, leaning-by-doing effects, and the acquisition of new knowledge from abroad, particularly through foreign direct investment.

Although trade liberalization does not necessarily imply exports growth, in practice both appear to be highly correlated. Moreover, the effect of trade liberalization on economic growth tends to occur mainly through efficiency improvements and exports stimuli that have powerful effects on both supply and demand within an economy. (THIRLWALL, 2000, p. 14) For these reasons, the empirical literature focused on robustness tests of results indicating the existence of a positive effect from exports to growth. An idea of the dimension of the empirical literature on the relationship between exports and growth is given by Giles and Williams (2000), who surveyed more than 150 applied studies. Still, these authors conclude that there is no obvious agreement in the debate about the outward oriented growth.

According to Giles and Williams (2000), the empirical literature on the ELG hypothesis may be separated into three groups. Early studies used cross-country correlation coefficients between exports and growth. Also relaying on the cross-country analysis the follower studies consisted of LS-based regression applications. The third group of works applied various time series techniques, such as causality and cointegration, to examine the exports-growth nexus usually based on individual country analysis. We add three other groups of studies to this classification. First, some recent studies have emerged concerning the importance of the composition of exports, as Fosu (1990), Funke and Ruhwedel (2001), Crespo-Cuaresma and Wörz (2005), and Herzer et al (2006), between others. Second, another group of studies have applied recent techniques of causality for panel data, as Ahumada and Sanguinetti (1995), and Kónya (2006). Finally, the last group of works, on which this work is included, is represented by the work of Foster (2006) who proposes the use of threshold regression techniques to examine whether any relationship between exports and growth depends upon a third variable.

Focusing on a comprehensive sample of African countries, Foster (2006) tested for the presence of thresholds in the relationship between exports and growth determined by the initial level of GDP per capita, the share of exports in GDP, and the growth of exports. Overall, his results suggest that there is a significant relationship between the rate of growth of exports and the rate of growth of output, and it is not necessary to be relatively developed in terms of initial income or to have a relatively large export base in order for this relationship to hold. The results also suggest the presence of diminishing returns to exporting.

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[2] This static gains idea is directly related to the Comparative Advantages Theory of David Ricardo classical economist.

On this context the main aim of this paper is to apply the panel threshold regression techniques, introduced by Hansen (1996, 1999 and 2000), in order to verify whether the export-led growth hypothesis holds in three different samples, and conditioned to three different threshold variables: the initial level of GDP per worker, the human capital level, and the exports share in GDP. Furthermore, our work pays special attention to the data construction procedure of 5-years averaging of the variables, using panel unit root tests, and to the choice of the adequate variables measures using a sensitivity analysis.

The paper is organized as follows. In Section 2 we briefly review some empirical issues on economic growth research. In Section 3 the methodology applied in this paper is discussed. In Section 4 we discuss the data sources, the samples, and the construction procedure. Section 5 presents the estimation results. Finally the paper ends with the concluding remarks.

2. Empirical Issues on Economic Growth

This section briefly reviews some of the major concerns on the recent economic growth empirical literature. As our main aim is not to extensively survey it, we rely on the aspects that we think are most relevant to our research, and recommend the interested reader to search details on the cited studies.

2.1. Sources of Growth

The main aim of growth studies is to understand why growth rates differ across countries. To address this question a wide variety of methods have been proposed, sometimes leading to divergent conclusions. Temple (1999, p. 119-125) proposes a classification dividing these methods into five groups: historical studies, growth accounting, growth regressions, informal growth regressions, and cross-country growth accounting.

The historical studies mostly rely on individual countries studies, which allow a deeper conception of the social, institutional and technological sources of growth, but providing only a partial view of the growth process, making it hard to generalize the results. The growth accounting studies focus on the contribution of inputs and total factor productivity (TFP) to growth, where the TFP growth is derived as a residual from the imposition of parameters to the production function based on factor shares or micro evidences, and thus, not explaining it. In the growth regression studies the cross-country variation in the data is used to estimate the parameters of an average production function, mostly of these studies relaying on the transitional dynamics specification of Mankiw, Romer and Weil (1992). The informal growth regressions studies, which are often called “Barro regressions” after Barro (1991), are ad hoc specifications of the growth regressions including other explanatory variables associated with technological progress. Finally, the cross-country growth accounting which may be thought as a mixture of the growth regressions and the growth accounting methods, where the first is used to estimate average output elasticities across countries and the latter to account the contribution of inputs and TFP to growth.

Another way to distinguish between growth studies relates to the role given by different theoretical frameworks to factor accumulation, technological progress, and national policies and institutions, as driving forces for the long run growth. The factor accumulation growth models are mainly derived from the seminal neoclassical models of Solow (1956), Cass (1965), and Koopmans (1965), which main prediction is that the countries will converge to a long run steady state conditioned to their production factors accumulation rates. The models that focus on the technological progress determinants are related to the endogenous growth models over which Jones (1995) distinguishes two classes: the "AK"-style growth models of Romer (1986, 1987), Lucas (1988), and Rebelo (1991); and the R&D-based growth models of Romer (1990), Grossman and Helpman (1991a, 1991b), and Aghion and Howitt (1992). Linking the technological change to the accumulable factors allocation, or to the process of creation and absorption of innovations, these models make the growth endogenous, some of them leading to different convergence results than that obtained from the neoclassical point of view (see Barro and Sala-i-Martin, 1995). Finally, according to the institutional view, pioneered by Acemoglu, Johnson and Robinson (2005), neither the neoclassical framework nor that of the NGTs informs us much about the ultimate sources of differences in economic performance.

This debate gave rise to a new classification of the sources of growth between the proximate, the wider, and the deep sources of growth. The proximate sources usually include the investment, the human capital, and the R&D. The wider class comprehends those other sources that work by indirectly effect through the proximate sources, or by direct effects through TFP, including the population growth, trade orientation, financial development, and others (TEMPLE, 1999, p.137-148). The deep sources of growth are derived from the institutional view, measuring the quality of institutions by different indices of accountability, property rights, rules of law, religion, degree of contract enforcement, government effectiveness, social capita, and others. As stated by Capolupo (2008, p. 21), is the interplay between these forces that drives the long run growth.

On the context of the export-led growth hypothesis, the effects of exports over growth could be classified as a wider source of growth, as much of the evidence suggests that these effects depend on countries characteristics such as the level of industrialization. Moreover, as emphasized in the Feder (1983, 1986) formulation the effects of exports on growth is thought to work in a disequilibrium situation, thus, not as a determinant of the long run steady state growth. That is to say that the export-led growth may be seemed more reliable on the context of the transitional dynamics growth of Mankiw, Romer and Weil (1992).

2.2. Model Uncertainty

One of the most highlighted research fields in the recent economic growth empirics has been the model uncertainty issue. The seminal work on this field is the Levine and Renelt (1992) sensitivity analysis, which mainly finding was that very few macroeconomic variables are robustly correlated with cross-country growth rates. An alternative model averaging procedure was proposed by Sala-i-Martin (1997), which yielded less severe results based on a less restrictive concept of robustness. Nevertheless, there are still many variables, that are theoretically expected to be important, that are found to be not significantly correlated with growth. These results together with the lack of agreed theoretical basis[3] has motivated the emergence of the model uncertainty studies, which consist of statistical procedures allowing the choice of the variables, their measures, and the model specification, based on the data.

Another recent approach to model uncertainty is the Bayesian Model Averaging (BMA), as applied by Doppelhofer, Miller and Sala-i-Martin (2004). Averaging OLS coefficients over 67 explanatory variables across models, the authors find that 18 are significantly partially correlated with long-term growth, and just 4 seem to be robustly associated with growth: the relative price of investment, the initial GDP per capita, primary schooling, and the number of years the country has been open. Further details on the BMA approach can be found in Raftery, Madigan and Hoeting (1997).

On this context of model uncertainty our empirical specification will be based on a sensitivity analysis where we adapt the model averaging procedure of Sala-i-Martin (1997) focusing on the measure choice problem. This procedure will be detailed at the estimation results section.

2.3. Human Capital Specification

According to Hanushek and Kimko (2000), two main questions arise in considering the effect of human capital on economic growth: (i) How to measure human capital? (ii) How to specify any relationship? The answers to these questions given by diverse studies have been surveyed in Wößmann (2000) work, which constitutes the basis for the discussion of this section.

On the measurement issue, traditionally the stock of human capital is considered as a function of education. From this relationship a wide variety of measure specifications have been proposed, including: education-augmented labor input, adult literacy rates, school enrollment ratios, average years of schooling, Mincerian human capital earnings function, and quality of education measures such as educational inputs, rates of return to education, and direct tests of cognitive skills.

From these measures, the Mincer specifications could be considered as the ones with the better theoretical background, especially when also considering decreasing returns to education. The Mincerian human capital earnings function transform education measured in units of time into the stock of human capital expressed in units of money. The decreasing returns are coupled to the specification by considering that each additional year of schooling raises earnings by the rate of return to the investment in education. Furthermore, the measure can be easily adjusted for educational quality differentials, if such a measure is available. For such reasons, our human capital measures will be computed based on this specification, as it will be further described in data construction section.

On the relationship specification between human capital and growth we can distinct between two main groups of theoretical views. The first one is the neoclassical view, which is derived from a human-capital-augmented neoclassical growth model by Mankiw, Romer and Weil (1992). By this view the accumulation of human capital is considered as a factor of production that drives economic growth, so

[3] According to Brock and Durlauf (2001), the inclusion or exclusion of most variables is typically arbitrary, a phenomenon labeled the “open-endedness” of growth theory.

that differences in levels of human capital stock are related to differences in output levels across countries, and growth rates of human capital stock should be connected to growth rates of income. Thus, the long-run growth is unaffected by the accumulation of human capital inputs, but this input accumulation leads to output growth along a transitional growth path from one steady-state to the next.

The second view is the one from the technical-progress theoretical framework, that is, the endogenous growth models, going at least as far back as Nelson and Phelps (1966). According to this view a greater human capital stock affects economic growth mainly by facilitating innovation and adoption of new technologies, so that differences in levels of human capital cause differences in output growth across countries.

Given the above discussion of model uncertainty we will leave to the sensitivity analysis to lead which of this possibilities is the best specification accounting for the human capital effects on growth.

2.4. Panel Data Approach

One of the first advocates of the panel data approach on the empirics of economic growth was Islam (1995). Focusing on the process of convergence the author argues that allowing for differences in the production function across countries, in the form of fixed individual country effects, the panel data approach allows to isolate the effect of capital deepening on the one hand, and, technological and institutional differences on the other. Thus, the specification of individual country effects came as a potential solution for the omitted variables problem in the framework of single cross-country and pooled regressions. Moreover, in a dynamic context, the usage of lagged regressors as instruments seems to alleviate measurement error and endogeneity biases (TEMPLE, 1999, p. 131-132). The panel specification of most growth studies can be summarized in the following form.

$$\dot{y}_{i,t} = \beta_1 y_{i,t-1} + \beta_2 X_{i,t} + \mu_i + \eta_t + \varepsilon_{i,t} \tag{2.1}$$

where $\dot{y}_{i,t}$ is the average growth rate over a series of five or ten-years period, $X_{i,t}$ is a vector of explanatory variables, μ_i and η_t are the country and time specific effects, $\varepsilon_{i,t}$ is a serially uncorrelated measurement error, and the subscripts *i* and *t* refer to country and period, respectively.

As the individual country effects term may be correlated with the explanatory variables the random effects specification, which is assumed to be uncorrelated with the exogenous variables, is generally not considered. The estimation techniques used to remove the fixed effects includes the within group estimator, and the generalized method of moments estimator (GMM). The first one requires a time series demeaning procedure, subtracting from each variable their within group means, while in the GMM the general approach is to estimate the equation in differences and to remove the country specific effects by using lagged levels of the regressors as instruments. (CAPOLUPO, 2008, p. 13-15)

However, the adoption of the panel data approach also has its own weaknesses: (i) the range over which average of variables are computed is shorter compared to cross-country studies, and hence, not adapted to capturing long run effects; (ii) the use of differenced variables changes the interpretation of regression results; (iii) some unjustifiable assumptions about parameter homogeneity; (iv) the problem of serial correlation in the errors needs to be further explored.

3. Methodology

This section discusses the methodology that we apply on this paper. Firstly, it briefly review the building procedure for Panel Threshold Regressions (PTR) based mainly on Hansen (1996, 1999 and 2000), thereafter turning to the empirical specification.

3.1. Panel Threshold Model

Threshold regression models allow individual observations to be divided into regimes based on the value of an observed variable. Firstly introduced into univariate time series context (see TONG, 1983), the seminal paper of Hansen (1999) introduced the econometric techniques appropriate for threshold regression with panel data. Allowing for fixed individual-effects the PTR model divides the observations into two or more regimes depending on whether a threshold variable is smaller or larger than a threshold value, and these regimes are distinguished by differing regression slopes.

From panel data of a dependent variable $y_{i,t}$, a vector of regressors $x_{i,t}$, a threshold variable $q_{i,t}$, and a threshold value of γ, the structural equation of interest is specified in the following eq. (3.1):

$$y_{i,t} = \mu_i + \beta_1' x_{i,t} I(q_{i,t} \leq \gamma) + \beta_2' x_{i,t} I(q_{i,t} > \gamma) + e_{i,t} \tag{3.1}$$

where $I(\bullet)$ is the indicator function which assumes the value of one (1) when the inner brackets condition is satisfied and zero (0) otherwise, μ_i is the fixed individual-effect, and $e_{i,t}$ is independent and identically distributed (i.i.d.) error term with mean zero and finite variance σ^2.

It is easy to see that the point estimates for the slope coefficients $\beta's$ are dependent of the given threshold value γ. Since the threshold value is not previously known and it is supposed to be endogenously determined, Hansen (1999) recommends a grid search selection of γ that minimizes the sum of squared errors (SSE) obtained by least squares estimates of equation (3.1). Moreover, it is undesirable for a threshold $\hat{\gamma}$ to be selected which sorts too few observations into one or the other regime, and so, it is also suggested that the search for the SSE minimizing threshold value to be restricted by eliminating the smallest and largest $\eta\%$ values of the threshold variable $q_{i,t}$ for some $\eta > 0$ [4].

After finding the estimate for the threshold value $\hat{\gamma}$ it is important to infer whether the threshold effect is statistically significant, which is equivalent to test the

[4] On the threshold autoregressive (TAR) time series models context, Enders (2004, p. 397) suggests to exclude the highest and lowest 15 percent, while Hansen (1999, p. 349) suggests to exclude 1 or 5 percent on the panel threshold regression (PTR) models context.

null hypothesis that $\beta_1 = \beta_2$. However, as the threshold γ is not identified under the H_0, classical tests have non-standard distributions. At this point, Hansen (1996) suggested a bootstrap procedure to simulate the asymptotic distribution of the likelihood ratio test of equation (3.2)[5]. The null of no threshold effect is rejected if the p-value obtained by the bootstrap procedure is smaller than the desired critical value.

$$F_1 = \frac{S_0 - S_1(\hat{\gamma})}{\hat{\sigma}^2} \tag{3.2}$$

where S_0 is the SSE obtained from the estimative of (3.1) under the null hypothesis of no threshold, S_1 is the SSE obtained from the PTR estimative of (3.1), and $\hat{\sigma}^2$ is the residual variance of the PTR regression.

Once the threshold effect is found to be significant, one would ask if the estimated $\hat{\gamma}$ is consistent for the true value of the threshold (γ_0). To form confidence intervals for γ Hansen (1999, p. 351) proposes the likelihood ratio statistic reproduced in equation (3.3), which under some technical assumptions has the critical values of 5.9395, 7.3523, and 10.5916, at the significance levels of 10%, 5%, and 1%, respectively. The asymptotic confidence interval for γ at a (1-α) confidence level is found by plotting $LR_1(\gamma)$ against γ and drawing a flat line at the critical level.

$$LR_1(\gamma) = \frac{S_1(\gamma) - S_1(\hat{\gamma})}{\hat{\sigma}^2} \tag{3.3}$$

Hansen (1999, p. 353) also extends the PTR model to test for multiple thresholds. The general approach is quite the same for the case of only two regimes, with just a few differences. The first one refers to the estimation procedure, which may be done by a three-stage (when there is only three regimes) sequential estimation of the two threshold parameters. The first stage refers to the same estimation procedure as presented for the single threshold model, which yields the first estimate $\hat{\gamma}_1$. Fixing this threshold parameter, the second stage estimates the second threshold parameter $\hat{\gamma}_2^r$ minimizing the SSE of equation (3.4). In the last stage, the first threshold parameter is re-estimated holding fixed the second threshold parameter. From this three-stage sequential estimation results the asymptotically efficient estimator of the threshold parameters, $\hat{\gamma}_1^r$ and $\hat{\gamma}_2^r$. Note that these estimators have the same asymptotic distributions as the threshold estimate in a single threshold model, which means that we can construct confidence intervals in the same way as we did before.

$$y_{i,t} = \mu_i + \beta_1' x_{i,t} I(q_{i,t} \le \gamma_1) + \beta_2' x_{i,t} I(\gamma_1 < q_{i,t} \le \gamma_2) + \beta_3' x_{i,t} I(\gamma_2 < q_{i,t}) + e_{i,t} \tag{3.4}$$

The second difference refers to the inference over the thresholds estimates. When the null of no threshold is rejected with the F_1 statistic, one needs a further test to discriminate between one and two thresholds. This test is done with a similar bootstrap procedure, but now simulating the distribution of the F_2 statistic (Eq. 3.5).

$$F_2 = \frac{S_1(\hat{\gamma}_1) - S_2^r(\hat{\gamma}_2^r)}{\hat{\sigma}^2} \tag{3.5}$$

[5] We encourage the reader to look at this procedure in Hansen (1999, p.350-1).

where S_1 is the SSE obtained from the first-stage estimative, S_2^r is the SSE obtained from the second-stage estimative, and $\hat{\sigma}^2$ is the residual variance of the second-stage estimative.

Finally, as González, Teräsvirta and van Dijk (2005) did outlining a three stage process for model building in the context of the panel smooth transition regression (PSTR) models, we outline our model building method for PTR models in three stages: specification, estimation and evaluation. On the specification stage we must test for the existence of thresholds against the linear hypothesis, also determining the appropriate number of thresholds. The second stage consists of the estimation of the selected models from the previous stage. Lastly, we evaluate the results calculating the confidence intervals for the threshold parameters, and confronting the estimated slope coefficients with the economic theory predictions.

3.2. Empirical Specification

From the discussion in the previous sections we derive the general empirical specification presented in the following equation (3.6).

$$\begin{aligned}\dot{y}_{i,t} = \beta_1 y_{i,t-1} + \beta_2 i_{i,t} + \beta_3 n_{i,t} + \beta_4 h_{i,t} + \\ + \delta_1 x_{i,t} I(q_{i,t} \leq \gamma) + \delta_2 x_{i,t} I(q_{i,t} > \gamma) + \mu_i + \eta_t + \varepsilon_{i,t}\end{aligned} \tag{3.6}$$

where $\dot{y}_{i,t}$ is the growth rate of output per worker, $y_{i,t-1}$ is a measure of the initial level of output per worker, $i_{i,t}$ is the ratio of investment to GDP, $n_{i,t}$ is the growth rate of the labor force, $h_{i,t}$ is a measure of human capital per worker, $x_{i,t}$ is a measure of exports output, $I(\bullet)$ is the indicator function, $q_{i,t}$ is one of the possible threshold variable (see below), γ is the threshold value, μ_i and η_t are the country and time specific effects, $\varepsilon_{i,t}$ is the i.i.d. error term with mean zero and finite variance σ^2, and the subscripts *i* and *t* refer to country and period, respectively.

Some remarks are important at this stage. First, it is straightforward to note that the general specification from equation (3.6) reduces to the linear case when the threshold variable is always smaller or larger than the threshold γ. Second, as this general specification is easily extensible for the multiple thresholds case, we omit this bigger specification though we will test for its presence in the PTR estimatives. Third, to deal with the model uncertainty and the measurement error issues we must try for different measures (where available) that could represent the same factor on the growth context. The data availability (see next section) restricts our sensitivity analysis to the following variables: the initial level of output per worker, the human capital measure, and exports output measure. The search for the best measure for these variables will be carried out only on the restricted linear model estimates, using an approach similar to that of Sala-i-Martin (1997).

Finally, in the panel threshold regressions context, we elect three factors as possible thresholds variables for the export-led growth hypothesis: the human capital stock per worker, the GDP per worker, and the exports share on GDP.

4. Data Sources, Construction and Sampling Procedures

4.1. Data Sources

The gross data comes mainly from the Penn World Tables v.6.2 (HESTON et. al., 2006) which offers internationally comparable annual macroeconomic data for almost all of the world economies. All the selected data refers to the constant prices entries and covers the period from 1974 to 2003. The unique exceptions are the human capital data which are computed into a five-year basis and are based on the average years of schooling by level from the Barro-Lee Dataset (BARRO; LEE, 2000) and the General Index of Qualitative Indicators of Human Capital (QIHC-G) recently built by Altinok and Murseli (2007). From these gross data we have followed Wößmann (2000) to construct two distinct measures of the stock of human capital both based on the Mincerian human capital theory with decreasing returns to education. While the first specification (Eq. 4.1) assumes identical quality of education, the second specification (Eq. 4.2) accounts for quality differentials in education between the countries.

$$H_{it}^{M} = e^{\sum_a r_a s_{ait}} \tag{4.1}$$

$$H_{it}^{Q} = e^{\sum_a r_a Q_i s_{ait}} \tag{4.2}$$

where r_a is the rate of return to education at level *a*, s_{ait} is the average years of schooling at level *a* for country *i* and period *t*, and Q_i is the QIHC-G for country *i*.

Two additional observations are important to mention about the construction of these human capital stocks series. First, as justified by Wößmann (2000, p.20) the rates of return to education are considered to be the same for all countries. These rates come from the estimates of the world-average social rates of return to education by Psacharopoulos (1994, Table 2) corresponding to 20.0% at the primary level, 13.5% at the secondary level, and 10.7% at the higher level. Second, the restricted availability of data on educational quality makes our measure of human capital stocks subject to the hypothesis that the differentials in the quality of education between the countries under analysis remained constant over the period.[6]

The other variables were all obtained directly or indirectly from the Penn World Tables constant price entries: the left hand economic growth variable and the first explanatory variable of initial income come from the real GDP chain per worker (RGDPWOK) variable; the investment rate comes from the investment share of the real GDP (Laspeyres) per capita (KI); the labor stock is obtained indirectly with the real GDP chain per capita (RGDPCH), the population (POP), and the real GDP chain per worker (RGDPWOK)[7]; the exports figures come indirectly by calculations with the openness index (OPENK) and the net foreign balance (KNFB)[8].

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[6] We have also tried to adjust the average years of schooling measure from the Barro-Lee Dataset, which refers to the population aged 15 and over, to a per worker basis using the ratio between the real GDP chain per worker (RGDPWOK) and the real GDP chain per equivalent adult (RGDPEQA) variables from the Penn World Tables, but our sensitivity analysis showed that this measure had a poor adjust.

[7] LAB=(RGDPCH*POP)/RGDPWOK.

[8] The net foreign balance as a percentage of the GDP can be obtained by the formula *100-KC-KI-KG=KNFB*, where *KC*, *KI*, and *KG* are the percentage shares of consumption, investment and government spending, respectively, in GDP. Then *Exports/GDP=(OPENK+KNFB)/200*.

Regarding the sensitivity analysis we have two different measures for the initial level of output per worker: the RGDPWOK from the previous year, and the averaged RGDPWOK from the previous five years. For the human capital measure we try on six different specifications: the growth rate of H_{it}^{M} and H_{it}^{Q}, which relates to the neoclassical specification of the human capital; the contemporaneous stock of human capital per worker given by H_{it}^{M} and H_{it}^{Q}, which relates to the endogenous growth models specification of the human capital; and the previous period stock of human capital per worker, which may account for endogeneity of the human capital stock. For the exports output variable we try on the three most common measures encountered on the empirical works: the exports share on GDP, the exports growth rate, and the product of these two.

Finally, to avoid business cycle effects the data was averaged over six five year periods. As we consider this a relevant step for the results obtained, details about the procedures will be given in Section 4.3.

4.2. Samples

The sample construction was divided into two steps. First, countries were selected based on several criteria: (i) data availability for the period from 1974 to 2003; (ii) exclusion of countries for which oil production is the dominant industry[9]; (iii) exclusion of countries whose data receive a grade "D" from the Penn World Tables (DEATON; HESTON, 2008, p. 41); (iv) exclusion of countries whose populations in 1974 were less than one million. This process resulted in the selection of a total of 72 countries.

The second step consisted of the samples selection for which the results will be reported. On this matter we consider six samples of countries selected by the World Bank (2009) income classification and the availability of the data on educational quality to allow the calculation of the measure of the human capital stock from equation (4.2). The detailed samples are presented in Table A of the Annex. The broader sample, which will be referred as (BROAD1), consists of the 72 countries selected in the previous step. The second sample consists of 34 countries from the first sample classified as Low and Lower Middle Income by the World Bank, and the third sample are the remaining 38 countries classified as Upper Middle and High Income countries. These samples will be referred as (LOW1) and (HIGH1), respectively. The next three samples follow the same income classifications, but are restricted by the data availability on educational quality. These consist of 57 countries (BROAD2), 22 countries (LOW2), and 35 countries (HIGH2), respectively.

Although the threshold panel data model can be thought as a sample-splitting by itself, sampling the countries by its income class goes in line with the condition of 'small' difference, relative to sample size, between the regimes slopes pointed out by Hansen (1999)[10]. By this way we will be able to infer whether the threshold effect

[9] The countries excluded on this basis are the same of Mankiw, Romer and Weil (1992) in addition to the OPEC countries: Algeria, Bahrain, Ecuador, Gabon, Iran, Iraq, Nigeria, Oman, Qatar, Saudi Arabia, United Arab Emirates, and Venezuela. Lesotho is also excluded because the sum of private and government consumption far exceeds GDP in most part of the years, indicating that labor income from abroad constitutes an extremely large fraction of GNP.

[10] Technically, $(\beta_i - \beta_j) \rightarrow 0$ as $n \rightarrow \infty$, where the β's refer to regimes slopes on the same variable.

holds only between countries with closest development levels, or between the countries on a broad basis.

4.3. Data Averaging Procedure

Despite the most part of the gross data described in Section 4.1 is available at an annual frequency, the emphasis on the long-run given by economic growth theories makes the usage of annual data a very questionable procedure even when the transitional growth dynamics are taken into account. Temple (1999, p. 119) suggested that trend growth rates should be more robust to short-run instability, such as business cycle effects. The most common procedure is to average the variables into five or ten-years timespan. However, the appropriateness of this procedure will depend on the time series properties of the variables. More specifically, the question is whether the variables of interest are trend stationary (TS) or difference stationary (DS). While in the former the trend growth rate is obtained regressing the log of the series on a constant and a time trend, in the latter case the trend growth rate is estimated regressing the first difference of the series on a constant. (ENDERS, 2004, chapter 4)

This discussion draws back (at least) to Nelson and Plosser (1982) results on time series unit root tests over important macroeconomic variables and its major relevance is related to business cycles studies, which is not the main point of this article. Therefore, we just present some results of panel unit root tests applied on the annual series from the previous sections. From the empirical specification given in equation (3.6) it is clear that the investment rate and the growth rate of the human capital stock variables do not need trend growth rate estimates. However, we also present results of panel unit root tests for this variable given the relevance of the stationarity assumption for the validity of regression results. The unit root tests are not applied to the human capital variable because it was already obtained on a five-year basis.

For robustness considerations we present results from several panel unit root tests: the LLC from Levin, Lin and Chu (2002); the Breitung (2000); the IPS from Im, Pesaran and Shin (2003); and two Fisher-type tests using ADF and PP[11] tests (Maddala and Wu (1999) and Choi (2001)). It is important to note that while the first two tests assume that there is a common unit root process, the later tests allow for individual unit roots across the cross-sections (the Fisher-type tests combine the p-values from individual unit root tests). The results testing for trend stationarity are presented in Table 4.1.

As it can be seem in Table 4.1, the only variable for which the null of a unit root process is strongly rejected (by all tests) is the rate of investment. Thus, this variable can be directly averaged for the threshold panel estimates. But for the other variables the null hypothesis is not rejected on all tests. These results indicate that these variables cannot be considered as TS, and so, the trend growth rates may not be calculated by regressing these variables on a constant and a deterministic trend. Yet, the DS hypothesis should be tested by means of unit root tests on the first difference of the variables. The results of these tests are presented in Table 4.2.

[11] ADF for Augmented Dickey-Fuller and PP for Phillips-Perron, which are the well known unit root tests for univariate time series.

Table 4.1 – Panel unit root tests on the logarithmic level of the variables with exogenous constant and trend, and one lagged dependent variable.

Variables/ Unit Root Tests	RGDPWOK		KI(1)		L		X	
	Stat(2)	p-val(3)	Stat(2)	p-val(3)	Stat(2)	p-val(3)	Stat(2)	p-val(3)
Common Unit Root Tests:								
LLC t*-stat4	-1.125	0.1303	-5.025	0.0000	0.111	0.5443	0.8514	0.8027
Breitung t-stat5	-0.845	0.1989	---	---	10.073	1.0000	2.4710	0.9933
Individual Unit Root Tests:								
IPS W-stat	-1.072	0.1418	-6.113	0.0000	4.496	1.0000	0.6454	0.7407
ADF-Fisher Chi-square	160.96	0.1583	261.35	0.0000	165.01	0.1109	133.23	0.7297
ADF-Choi Z-stat	-1.134	0.1284	-6.058	0.0000	4.279	1.0000	0.6783	0.7512
PP-Fisher Chi-square4	159.66	0.1762	294.27	0.0000	149.96	0.3498	121.76	0.9107
PP-Choi Z-stat4	0.722	0.7648	-7.010	0.0000	13.071	1.0000	0.6572	0.7445

Notes: (1) The unit root tests for the investment rate are the only where the exogenous trend is not included, and the variable is not in logs, as the concern is only with the stationarity of this variable.
(2) Null hypothesis of a unit root.
(3) Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.
(4) For the tests that require spectral estimation it was used the Bartlett kernel method with Newey-West bandwidth selection.
(5) The Breitung Panel Unit Root test is estimated only when exogenous constant and trend are included.

Table 4.2 – Panel unit root tests on the first difference of the logarithmic variables with an exogenous constant, and one lagged dependent variable.

Variables/ Unit Root Tests	RGDPWOK		L		X	
	Stat(1)	p-val(2)	Stat(1)	p-val(2)	Stat(1)	p-val(2)
Common Unit Root Tests:						
LLC t*-stat(3)	-11.446	0.0000	-2.299	0.0107	-11.516	0.0000
Individual Unit Root Tests:						
IPS W-stat	-17.660	0.0000	-1.928	0.0269	-20.393	0.0000
ADF-Fisher Chi-square	593.80	0.0000	212.62	0.0002	690.44	0.0000
ADF-Choi Z-stat	-17.055	0.0000	-1.712	0.0435	-19.303	0.0000
PP-Fisher Chi-square(3)	952.35	0.0000	165.67	0.1044	1215.95	0.0000
PP-Choi Z-stat(3)	-24.060	0.0000	0.210	0.5832	-29.240	0.0000

Notes: (1) Null hypothesis of a unit root.
(2) Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.
(3) For the tests that require spectral estimation it was used the Bartlett kernel method with Newey-West bandwidth selection.

The picture emerging from the results in Table 4.2 strongly favors the DS hypothesis for the output per worker and exports variables. The exception is the labor series for which the presence of a unit root process is rejected in four out of the six panel unit root tests. However, additional tests on the PP-type tests showed that the results are quite sensible to the chosen Kernel method for the spectral estimation and the bandwidth selection[12]. Based on these results we can conclude that the output per worker, the labor stock, and the exports series of our sample are DS around a mean value.

As previously discussed the time series comportment of the focused variables give us directions on the appropriate procedure for the five-year averaging of the data. The non-rejection of the DS hypothesis leads to the procedure of directly averaging the growth rates of the variables by taking its five-year means.

5. Estimation Results

On this section we present some estimation results for the model specified in equation (3.6). Our presentation sequence follows the same order that we proposed as our estimation approach. That is, firstly we present the results for the sensitivity analysis at the linear specification, and then our focus goes to the panel threshold estimates. Some summary statistics are presented in Table 5.1.

Table 5.1 – Summary statistics.

Variables		Broad Sample Statistics					
		Mean	Median	Max.	Min.	Std.Dev.	Obs.
Output per worker Growth	$\dot{y}_{i,t}$	1,20%	1,40%	11,19%	-11,46%	2,64%	432
Initial Level of Output per worker	$y_{i,t-1}$	19.481	14.118	63.306	962	15.729	432
	avg5	18.931	14.113	59.695	975	15.238	432
Investment Rate	$I_{i,t}$	16,91%	16,73%	53,87%	2,40%	8,39%	432
Labor Force Growth	$n_{i,t}$	2,07%	2,20%	8,63%	-0,88%	1,14%	432
Mincerian Human Capital	$\dot{H}^{M}_{i,t}$	6,34%	4,34%	87,08%	-11,81%	8,49%	432
	$H^{M}_{i,t-1}$	3,01	2,54	7,58	1,00	1,49	432
Quality-adjusted Human Capital	$\dot{H}^{Q}_{i,t}$	4,55%	3,12%	49,85%	-9,91%	5,84%	342
	$H^{Q}_{i,t-1}$	2,66	2,31	6,17	1,00	1,31	342
Exports	X/Y	29,00%	23,07%	201,29%(1)	3,67%	23,64%	432
	$\dot{X}$	5,30%	5,10%	25,02%	-17,33%	5,05%	432

Notes: (1) Hong Kong, Malaysia and specially Singapore are the only countries on our sample that show exports higher than GDP, which is probably due to the high re-exports figures of the Asian Tigers.

5.1. Linear Specification and Sensitivity Analysis

Our sensitivity analysis is similar to that of Sala-i-Martin (1997). The basic idea is to draw the distribution of the slope coefficient estimators of a variable of interest

[12] With the Parzen and the Quadratic spectral kernel methods, the PP-Fisher Chi-square test rejects the null hypothesis at the 5% significance level.

averaging these estimators over all the possible specifications and letting fixed the variable of interest and some others variables that are considered to appear in all regressions, that is, those variables that are known to be robust in advance. Although the aim of the methodology proposed by Sala-i-Martin (1997) is to check the robustness of a large set of explanatory variables on the specification of growth equations, we want to search for the best model specification (which variables to include) and the best variables specification (which measure and functional form to use for each variable) in the linear specification of equation (3.6). To do this we adapt the procedure to allow choosing, at the same time, which variables to include and which measure/functional form to use for each variable.

Given that we have a shorter number of variables, but different measures for some of them, the first adaptation in the method refers to the form that the combinations are made. On this regard we postulate some rules to guide us through the method: (i) the sensitivity analysis should be done on every variable for which there is data availability of more than one measure, or more than one possible functional form to enter into the model specification, and those variables that do not meet this condition should be considered as a fixed variable; (ii) one measure of each explanatory variable should be included in each regression; (iii) for each variable measure or functional form that the sensitivity analysis is applied, every possible combination with the other explanatory variables measures should be a regression.

From the first rule and the data availability discussed earlier we can define our fixed and not fixed variables. The only variable for which we do not use more than one measure and neither try different functional forms is the labor growth. So, this variable will be present at every regression. All the other variables will be tested for different measures or specifications, as it is presented in the first two columns of Table 5.2.

The second adaptation in the method refers to the way we calculate the confidence probabilities. On Sala-i-Martin (1997) the probabilities are calculated over the side[13] where the larger area of the distribution lies, regardless of whether this is in accordance with the theoretically expected sign for the variable. This is justifiable when the expected sign for the variable is ambiguous, which is not the case for the variables here considered. So, the probabilities we calculated refer to the areas lying on the theoretically expected side for each variable: positive for investment, human capital and exports; and negative for the initial level of output per worker.

Another minor difference in our approach is that we use panel data regressions instead of cross-country regressions. This allows us to include country-specific effects, as well as time-specific effects on the formulation. The regressions were estimated by the LSDV with fixed country and time-specific effects.

After these considerations we ran our sensitivity analysis procedure which consisted of 1280 regressions for each sample (Table 5.2). The results do not differ qualitatively between the BROAD and the HIGH samples, meaning that the best specification for each variable does not change between these two samples. For the LOW sample the results indicated a different specification choice for the initial GDP per worker, and the human capital variables. However, the difference between the probabilities are negligible, so as to lead us to decide to use only the specification

[13] Zero divides the area under the density in two.

given by the sensibility analysis on the broader sample. From the results in Table 5.2, the first two probabilities measures refer to the first case from Sala-i-Martin (1997, p.179-180), where the distribution of the slope parameter estimates is assumed to be normal, while the last two measures refer to the second case where that distribution is assumed to be not normal. Notice also that while the first and the third measures are obtained with the likelihood-weighted scheme, the second and the last measures are computed as unweighted averages.

Table 5.2 – Results for the sensitivity analysis procedure.

Variables		Average Estimates		Confidence Probabilities				No Regs
		Coefs.	Std.Dev.	Normal		Not Normal		
				Weight.	Unweig.	Weight.	Unweig.	
Initial Level of Output per worker ($y_{i,t-1}$) (avg5)	$y_{i,t-1}$	$-1.27\text{x}10^{-6}$	$3.62\text{x}10^{-7}$	0.9998	0.9998	0.9976	0.9977	160
	avg5	$-1.26\text{x}10^{-6}$	$3.79\text{x}10^{-7}$	0.9995	0.9996	0.9956	0.9960	160
	$\ln(y_{i,t-1})$	-0.042394	0.007131	**1.0000**	**1.0000**	**1.0000**	**1.0000**	80
	ln(avg5)	-0.043803	0.007438	1.0000	1.0000	0.9999	0.9999	80
Investment Rate ($I_{i,t}$)	$I_{i,t}$	0.110922	0.030788	0.9998	0.9998	0.9988	0.9987	80
	$\ln(I_{i,t})$	0.021365	0.005494	**0.9999**	**0.9999**	**0.9997**	**0.9997**	80
Exports (X)	X/Y	0.022728	0.014009	0.9476	0.9489	0.9409	0.9422	80
	$\dot{X}$	0.169591	0.025713	1.0000	1.0000	1.0000	1.0000	80
	$\dot{X} \cdot X/Y$	0.554394	0.078170	**1.0000**	**1.0000**	**1.0000**	**1.0000**	80
	$\ln(X/Y)$	0.008333	0.005902	0.9210	0.9154	0.8933	0.8878	80
Mincerian Human Capital	$\dot{H}^M_{i,t}$	-0.029794	0.013326	0.0127	0.0128	0.0155	0.0156	32
	$H^M_{i,t}$	-0.000483	0.003996	0.4519	0.4502	0.4590	0.4573	32
	$H^M_{i,t-1}$	0.004262	0.003639	**0.8792**	**0.8780**	**0.8672**	**0.8660**	32
	$\ln(H^M_{i,t})$	-0.044794	0.013616	0.0005	0.0005	0.0023	0.0022	32
	$\ln(H^M_{i,t-1})$	-0.009570	0.011805	0.2088	0.2061	0.2625	0.2601	32
Quality-adjusted Human Capital	$\dot{H}^Q_{i,t}$	-0.050404	0.020975	0.0081	0.0082	0.0138	0.0139	32
	$H^Q_{i,t}$	0.004172	0.005306	0.7842	0.7840	0.7802	0.7800	32
	$H^Q_{i,t-1}$	0.009251	0.004716	**0.9751**	**0.9750**	**0.9730**	**0.9729**	32
	$\ln(H^Q_{i,t})$	-0.019618	0.020294	0.1668	0.1658	0.1912	0.1902	32
	$\ln(H^Q_{i,t-1})$	0.018280	0.016641	0.8640	0.8625	0.8164	0.8149	32

Notes: The bold probabilities are the best choice for each variable.

With these results in hand it rests just to formulate the final linear specification choosing the robust variables and their best measures/functional forms. On the robustness issue we decided to select all the variables, even thought the Micerian specification of the human capital variable would not pass on 95% confidence level of robustness. As excluding this variable from the linear specification could be considered too radical regarding its emphasized relevance in other empirical works, we leave it as an alternative specification. Still, the results for the human capital variables are interesting as the best adjust were obtained with the lagged specification. We interpret this as evidence that using the lagged variable helps to avoid for the endogeneity problem in the determination of this variable.

The choice of the best measures and functional forms of the robust variables is done by comparing the probabilities between the measures of each variable, where the best are those that have the bigger probabilities. This leads us to choose the following measures: the log of the real GDP per worker from the previous year to represent the initial level of output per worker, the log of the share of investment in output as the investment variable, and the product between exports share on GDP and exports growth rate representing the exports variable. The estimative of this final specification is presented at Table 5.3.

Table 5.3 – Linear specification results.

Variables and Tests	Samples					
	BROAD1	HIGH1	LOW1	BROAD2	HIGH2	LOW2
Cross-section Effects Test(1)	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Period Effects Test(1)	None	Fixed	Fixed	None	Fixed	None
Initial Output per worker - $\ln(y_{i,t-1})$	-0.0452 (-5.96)***	-0.0786 (-8.05)***	-0.0283 (-2.78)***	-0.0484 (-4.82)***	-0.0862 (-7.71)***	-0.0325 (-2.43)***
Investment rate - $\ln(I_{i,t})$	0.0246 (3.80)***	0.0429 (5.34)***	0.0141 (1.78)**	0.0176 (3.67)***	0.0436 (5.00)***	0.0121 (2.01)**
Labor force growth - $n_{i,t}$	-0.5357 (-1.97)**	-0.2618 (-1.14)	-0.4270 (-1.13)	-0.7474 (-2.82)***	-0.2658 (-1.12)	-1.0196 (-2.64)***
Mincerian Human Capital - $H^M_{i,t-1}$	0.0047 (1.94)**	0.0075 (3.18)***	-0.0034 (-0.28)	---	---	---
Quality-adjusted Human Capital - $H^Q_{i,t-1}$	---	---	---	0.0100 (2.96)***	0.0123 (3.79)***	0.0040 (0.22)
Exports - $\dot{X} \cdot X/Y$	0.5985 (6.89)***	0.4395 (5.98)***	0.9205 (5.22)***	0.4942 (6.15)***	0.4587 (5.15)***	0.5583 (3.70)***
Observations (N x T)	72 x 6	38 x 6	34 x 6	57 x 6	35 x 6	22 x 6
R-squared	0.5294	0.6441	0.5633	0.5242	0.6430	0.5231
F-statistic	5.25***	6.93***	4.80***	5.06***	6.75***	4.43***
Akaike info. criterion	-4.8307	-5.5779	-4.4658	-5.0112	-5.6286	-4.5552

Notes: - t-statistics are reported in brackets. All models estimated using White Heteroscedasticity consistent standard errors and covariance.

- *, **, *** indicate unilateral statistical significance at the 10, 5 and 1 percent level respectively.

(1) The cross-section and period effects specification were tested using the Hausman test (see Wooldridge, 2002, p. 288) to compare the fixed and the random effects estimates of the coefficients, and a Likelihood Ratio test to detect redundant fixed effects.

Some remarks about these results seem to be appropriate to mention. First, holding our attention to the first three samples, the redundancy of the period fixed effect on the broader sample while rejecting this hypothesis for the shorter samples indicates that the period effects on the high and the low income countries may be annulling itself in the sum. In fact, inspection of these estimated effects allowed us to observe that on the first four periods of the sample (1974-78, 1979-83, 1984-88, 1989-93) the period effects were estimated to have contrary signals between the high and low income countries.

A second observation regards the insignificance of some of the labor force growth and human capital coefficients. While using the Mincerian human capital measure the labor variable was found to be insignificant both for high and low income countries, using the quality-adjusted measure the labor remains insignificant only for the high income countries. Together with the observation that the human capital has insignificant growth effects on the low income countries, these results indicate that what matters for countries which have already attained a high level of development is the human capital stock, while for the underdeveloped countries the labor force growth still constitutes an important restriction to growth. Also, notice that the coefficients estimatives for the different human capital variable specifications indicate that the quality-adjusted measure predicts a stronger effect of human capital on growth. This could also be inferred by paired comparison of the Akaike adjustment measure, which is overall higher for the regressions with the quality-adjusted measure of human capital.

Another important issue is the comparative interpretation of the other variables coefficient estimatives between the samples. For the initial output per worker slope coefficient, bigger absolute values imply a faster convergence to the steady state growth path. Thus, the results indicate that the conditional convergence occurs in a faster way on the high income countries than in the low income ones, and that accounting for quality of education on the human capital measure raises the rate of convergence. The results for the investment rate indicate that while for the high income countries an increase of 1% in the investment share in output is related to an increase of about 4 percent points in the growth rate, the same 1% increase in the investment share of low income countries is related to an increase of only 1 p.p. in the growth rate. This result should not be taken as evidence against the hypothesis of diminishing returns to physical capital accumulation, as the investment rate enters the specification on logs. Instead, it may be explained by the fact that the high income countries have higher investment rates (20.29% on average) than the poorer ones (10.23% on average), thus a change of 1% represents a bigger slice for the former than for the latter countries.

Finally, the exports variable appears to have a robust influence on growth. Overall the effect of exports on growth is stronger on the low income countries. This result is in accordance with the finding of diminishing returns to exports by Foster (2006), as the low income countries exports measure here considered has an average value of about 50% of the average value for the high income countries. However, an interesting result is that considering the quality-adjusted human capital measure lowers considerably the difference between the slope estimates of the export variable. This result raises the question of whether the diminishing returns to exports are not just an indirect effect of the countries human capital endowment.

5.2. Panel Threshold Regression Estimates

To a further understanding about the conditioning factors that makes the exports effects on growth differ across countries, on this section we search for the existence of thresholds in this relation applying the technique introduced by Hansen (1999). As previously outlined we consider as possible thresholds the initial level of output per worker, the human capital measures, and the share of exports on GDP.

The thresholds were estimated over our six sample definitions, where the latter three only differ on the human capital measure, totaling 18 threshold estimative procedure executions. The procedure searches from one to three multiple thresholds, which means that we allow a maximum of four regimes for each estimative. It is important to mention that the fixed effects specifications were based on the results obtained on the linear estimatives from the previous section.

The first step of our model building method refers to the number of thresholds specification test. This is done by bootstrapping the F statistic of equations (3.2) and (3.5). The results are presented at Table 5.4.

Table 5.4 – Tests for threshold effects.

Threshold Variable	Sample	Single Threshold		Double Threshold		Triple Threshold	
		F_1	p-value(1)	F_2	p-value(1)	F_3	p-value(1)
Initial Output per worker $\ln(y_{i,t-1})$	**BROAD1**	**18.54**	**0.0250**	**13.99**	**0.0520**	12.69	0.1830
	HIGH1	**18.78**	**0.0079**	6.19	0.3140	4.34	0.4840
	LOW1	7.36	0.3090	11.56	0.0590(2)	10.97	0.2840
	BROAD2	5.79	0.5390	10.96	0.0950(2)	2.63	0.9060
	HIGH2	**17.24**	**0.0290**	7.38	0.2670	5.18	0.4280
	LOW2	7.01	0.3780	5.61	0.4550	5.74	0.4960
Mincerian Human Capital $H^M_{i,t-1}$	**BROAD1**	**28.36**	**0.0040**	2.18	0.9910	1.68	0.9950
	HIGH1	9.70	0.2280	5.96	0.5420	10.48	0.0610(2)
	LOW1	10.78	0.1140	2.50	0.9370	3.31	0.7180
Quality-adjusted Human Capital $H^Q_{i,t-1}$	BROAD2	8.12	0.3830	7.32	0.3500	5.09	0.5210
	HIGH2	**15.46**	**0.0590**	12.81	0.1130	10.27	0.1280
	LOW2	7.64	0.2810	4.76	0.6240	2.64	0.8900
Exports share on GDP X/Y	BROAD1	9.13	0.2180	6.79	0.3390	3.53	0.7690
	HIGH1	**14.25**	**0.0420**	6.37	0.4150	6.17	0.3150
	LOW1	5.91	0.4210	4.60	0.5610	4.73	0.4910
	BROAD2	5.51	0.5750	3.70	0.7580	6.83	0.2630
	HIGH2	**14.82**	**0.0380**	8.81	0.1880	5.73	0.4320
	LOW2	5.62	0.4860	28.76	0.0010(2)	6.51	0.2990

Note: The specifications where threshold effects are found to be significant are in bold.
(1) p-values obtained by 1000 bootstrap replications.
(2) Although the marked bootstrapped p-values seem to indicate the existence of two or three thresholds, by construction, the multiple threshold tests are valid only when the first threshold effect is found to be significant.

The first conclusion that can be drawn from the results is that the linear specification is the best one for the sample of low income countries, as no threshold is found to be significant in any specification for this group. Second, with the quality-adjusted measure of human capital (all the samples ending with 2) threshold effects are found only for the high income countries. Finally, for the broader sample threshold effects are found only when considering as threshold variables the initial level of output per worker, and the Mincerian human capital measure, while the first case represents the unique evidence on double thresholds.

Focusing on those threshold estimates that were found to be significant, Table 5.5 reports the point estimates of the thresholds and their asymptotic 95% confidence intervals. These results are useful to see how each threshold variable divides the samples into the respective regimes. Overall the regime changing points are found below the median value of every threshold variable. For the double thresholds model the regimes are divided by the approximated values of U$3.320, U$5.086, and U$21.250 GDP per worker. Given that the income sampling that we have used has its dividing value of U$3.705 (based on the World Bank classification) these results show that the relationship between exports and growth for the low income countries is somehow homogeneous. Moreover, the second regime GDP per worker band comprehends that classification change point value, which indicates that countries in transition between the low and the high income classification may exhibit a different pattern on the exports and growth relationship.

Table 5.5 – Threshold estimates.

Threshold Variable	Sample	Threshold Number	Estimate	Percentile	95% Confidence Interval
Initial Output per worker $\ln(y_{i,t-1})$	BROAD1	1	8.1075	15th	[7.9345, 8.2437]
		2	8.5343	20th	[8.5343, 8.7814]
	HIGH1	1	9.9641	31th	[9.9407, 10.1026]
	HIGH2	1	9.9641	25th	[9.9461, 10.1026]
Mincerian Human Capital $H^{M}_{i,t-1}$	BROAD1	1	1.7265	20th	[1.4993, 1.7355]
Quality-adjusted Human Capital $H^{Q}_{i,t-1}$	HIGH2	1	2.5865	30th	[2.3340, 4.3706]
Exports share on GDP X/Y	HIGH1	1	0.1116	14th	[0.0643, 0.1266]
	HIGH2	1	0.1116	16th	[0.0813, 0.4815]

Still from Table 5.5, also notice that the threshold on the initial output per worker dividing the high income countries was found to be independent from the human capital measure used. This result also appears with the threshold on the exports share on GDP, and as the use of the quality-adjusted measure of human capital reduces the number of countries on the sample, the remaining discussion will disregard the estimation results using that samples ending with the number 2, as their threshold results seems to be irrelevant[14]. Table 5.6 reports the slope estimates of the exports variable over the different thresholds. The other variables coefficients were omitted from these results as they do not change significantly from the linear specification estimatives.

Table 5.6 – Exports coefficients estimates over the thresholds.

Threshold Variable	Sample	Regressor	Coefficient Estimate	t-Statistic(1)	Obs
Initial Output Per worker	BROAD1	$x_{i,t}I(\ln(y_{i,t-1}) \leq 8.1075)$	0.5524	2.9061	67
		$x_{i,t}I(8.1075 < \ln(y_{i,t-1}) \leq 8.5343)$	2.2159	5.0027	23
		$x_{i,t}I(8.5343 < \ln(y_{i,t-1}))$	0.5194	7.7358	342
	HIGH1	$x_{i,t}I(\ln(y_{i,t-1}) \leq 9.9641)$	0.2316	3.0994	72
		$x_{i,t}I(9.9641 < \ln(y_{i,t-1}))$	0.6086	8.0330	156
Mincerian Human Capital	BROAD1	$x_{i,t}I(H^{M}_{i,t-1} \leq 1.7265)$	1.5065	5.4300	88
		$x_{i,t}I(1.7265 < H^{M}_{i,t-1})$	0.4921	7.0060	344
Quality-adjusted Human Capital	HIGH2	$x_{i,t}I(H^{Q}_{i,t-1} \leq 2.5865)$	0.2332	2.5773	64
		$x_{i,t}I(2.5865 < H^{Q}_{i,t-1})$	0.4943	6.4470	146
Exports share on GDP	HIGH1	$x_{i,t}I(X_{i,t}/Y_{i,t} \leq 0.1116)$	2.1648	5.3009	34
		$x_{i,t}I(0.1116 < X_{i,t}/Y_{i,t})$	0.4272	6.6961	194

Notes: (1) t-statistics are calculated using White Heteroscedasticity consistent standard errors and covariance. All the coefficient estimatives are statistical significant at the 1 percent level.

The results for the three regimes model indicate that the stronger effect from exports to growth is observed on those countries with an initial output per worker between U$3.320 and U$5.086 which included: Cameroon (1974-83), China (1994-98), Republic of Congo (1974-83; 1994-98), India (1984-98), Indonesia (1984-98), Pakistan (1974-88), Senegal (1964-93), Sierra Leone (1974-78; 1984-93), Sri Lanka (1974-83), Syria (1974-78), and Thailand (1974-83). While on the two extreme regimes the effect is not too different from that calculated by the linear specification, on the transitional group the effect of exports on growth is about 3.7 times bigger.

A different picture emerges considering the sample of the high income countries. The threshold estimatives divide the sample around the GDP per worker value of U$21.250, where the countries in the lower group had weaker effects from exports to growth of 38% compared to the richer countries. The lower group includes: Brazil (1974-2003), Chile (1974-93), Costa Rica (1974-2003), Hong Kong (1974-78), Hungary (1974-88; 1994-98), Jamaica (1974-2003), Republic of Korea (1974-93),

[14] However, the threshold on the quality-adjusted measure of human capital is still relevant for us.

Malaysia (1974-98), Mexico (1974-2003), Panama (1974-2003), Poland (1974-2003), Portugal (1979-88), South Africa (1974-2003), Turkey (1974-2003), and Uruguay (1974-93). This result is at least disconcerting considering that the lower group includes countries broadly known as examples of the export-led growth hypothesis such as the Asiatic Tigers.

For the human capital thresholds, the results may be compared with caution. While with the Mincerian measure there is evidence of stronger effects from exports to growth in the countries with lower human capital stock, with the quality-adjusted measure the evidence indicates that the stronger effect happens on the countries with higher human capital stock. Even though these conclusions seem to be contradictory, they are based on distinct samples, and so, they are not directly comparable. One interpretation that we may have is that the exports effects on growth are high on the least developed countries (in terms of human capital) until a certain point from which the human capital starts to play a major role conditioning these effects. In fact, the results on the exports share on GDP threshold corroborate this idea. The estimated exports slope coefficient for those countries with exports share less than 11% is about five times bigger than the coefficient estimated for the more outward oriented countries.

Conclusions

This paper proposes a reassessment of the export-led growth hypothesis focusing on conditioning effects from countries initial level of GDP per worker, human capital stock, and exports share in GDP. For this purpose a panel threshold regression technique, introduced by Hansen (1996, 1999 and 2000), was applied over selected cross-country panel data, covering 72 countries and the period from 1974 to 2003, obtained mainly from the Penn World Tables v.6.2 (HESTON et. al., 2006). The analysis was featured by the distinction between two sub-samples by the World Bank (2009) income classification. Additionally, special attention was given to the commonplace data construction procedure of 5-years averaging of the variables, and to the variables measures choice, especially regarding the Wößmann (2000) recommendation of adjusting the human capital measure to educational quality differentials across countries.

Panel unit root tests were used to choose the appropriate way to obtain trend growth rates. These tests resulted in the rejection of the trend stationarity hypothesis while not rejecting the difference stationarity hypothesis, thus leading to the procedure of directly averaging the growth rates of the variables by taking five-year means over its logarithmic difference.

Taking account of the recent model uncertainty issue on economic growth empirical studies, a sensitivity analysis was proposed adapting the Sala-i-Martin (1997) method to the issue of choosing the robust measures for mostly variables of interest. An interesting result obtained by this method is that the best measure of human capital for growth regressions is a stock rather than a variation measure, favoring the formulations given by endogenous theoretical growth models against the neoclassical framework.

From the estimation results, the first finding was that, overall, the most common determinants of growth (initial level of output per worker, investment rate, labor force growth, and human capital stock) were found statistically significant, with only the labor force growth and the human capital stock variables showing some sample choice sensibility. One conclusion derived from these results was that for countries which have already attained a higher level of development is the human capital stock which matters, while for the underdeveloped countries the labor force growth still constitutes an important restriction on the growth context. Another shortcoming filled by our results relates to the importance on considering educational quality differentials across countries, where we found evidence favoring the superiority of the quality-adjusted measure of human capital stock against the measure only adjusted for the returns to education (Mincerian specification).

Focusing our attention to the exports variable, it was found that the exports effect on growth is positive, statistically significant, and robust to sample choice. The search for threshold effects from the initial output per worker, the human capital stock, and the exports share on GDP did make it possible to have a better understanding of how these growth determinants condition the existent link between exports and growth. The first conclusion obtained on this basis is that within the low income countries group the effect of exports on growth is homogenous, as no significant threshold was found in this sample. But this does not imply homogeneity between the groups of high and low income countries. Actually, the results for the broader sample show the existence of three regimes conditioned to the initial level of output per worker and two regimes conditioned to the Mincerian human capital measure. Additional thresholds were found statistically significant specifically within the high income countries for the threshold variables of initial level of output per worker, the quality-adjusted human capital stock, and the exports share on GDP.

Other main conclusions obtained from the results are: (i) countries in transition between the low and the high income classification, specifically between the output per worker band from U$3.320 to U$5.086, tend to exhibit stronger effects from exports to growth; (ii) between the countries classified as high income, those with GDP per worker lower than U$21.250 had weaker effects from exports to growth than the others; (iii) the effects from exports to growth are higher on the countries with lower levels of human capital stock and lower shares of exports on GDP (less than 11%), but these effects become lower when the exports share grow, and, at this point, the level of human capital starts to play a bigger role conditioning the enhancement of the exports effects on growth.

It is interesting to notice that the second point on the previous paragraph is at least disconcerting considering that the group with GDP per worker lower than U$21.250 includes countries broadly known as examples of export-led growth hypothesis such as the Asiatic Tigers. Moreover, the third point constitutes evidence of composed threshold effects between the level of human capital stock and the exports share on GDP, which could be thought as determinants of possible stages of growth on the context of the underdevelopment traps of Azariadis and Drazen (1990).

By the way, exploring the possibility of interactions between thresholds is our first recommendation for future research. Other extensions for this work are: (i) inclusion of institutional and geographic variables into the analysis, where an approach that may be very fruitful is that of Frankel, Romer and Cyrus (1996) who used trade shares predicted by a gravity model as instruments for actual trade share; (ii) the panel smooth transition regressions technique of González, Teräsvirta and van Dijk (2005) may give an even better picture on the regime transition context; (iii) the causality issue remains as an open question in the context of threshold regressions, even thought a Granger Causality test allowing for threshold effects has already been proposed by Li (2006).

As final words, we may say that this article presents strong evidences favoring the export-led growth hypothesis. Furthermore, the relationship between exports and growth was showed to be not as trivial as linear specifications would indicate.

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Appendix

A. Country Samples

Continent / Income Class	**Low and Lower Middle Income** (obs. = 34)	**Upper Middle and High Income** (obs. = 38)
Africa (obs. = 19)	Benin (BEN), Cameroon (CMR), Republic of Congo (COG)*, Egypt (EGY), Ghana (GHA), Jordan (JOR), Kenya (KEN), Malawi (MWI), Mali (MLI), Rwanda (RWA)*, Senegal (SEN), Sierra Leone (SLE)*, Syria (SYR)*, Tanzania (TZA), Tunisia (TUN), Zambia (ZMB), Zimbabwe (ZWE).	Israel (ISR), South Africa (ZAF).
America (obs. = 19)	Bolivia (BOL), Colombia (COL), Dominican Republic (DOM), El Salvador (SLV)*, Guatemala (GTM)*, Honduras (HND), Nicaragua (NIC)*, Paraguay (PRY), Peru (PER)*.	Argentina (ARG), Brazil (BRA), Canada (CAN), Chile (CHL), Costa Rica (CRI)*, Jamaica (JAM)*, Mexico (MEX), Panama (PAN)*, United States (USA), Uruguay (URY).
Asia/Oceania (obs. = 16)	China (CHN), India (IND)*, Indonesia (IDN), Nepal (NPL)*, Pakistan (PAK)*, Philippines (PHL), Sri Lanka (LKA)*, Thailand (THA).	Australia (AUS), Hong Kong (HKG), Japan (JPN), Republic of Korea (KOR), Malaysia (MYS), New Zealand (NZL), Singapore (SGP), Turkey (TUR).
Europe (obs. = 18)		Austria (AUT), Belgium (BEL), Denmark (DNK), Finland (FIN), France (FRA), Germany (GER), Greece (GRC), Hungary (HUN), Ireland (IRL), Italy (ITA), Netherlands (NLD), Norway (NOR), Poland (POL), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), United Kingdom (GBR).

Note: *Countries without data on the quality of education, which counts to 12 for the Low and Lower Middle Income Class and 3 for the Upper Middle and High Income Class.